A MOUSE WITH EARS EXPLORES MAPS

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ABSTRACT

This paper describes a set of techniques designed to assist visually impaired and blind users build mental models of geographic maps without the use of special hardware beyond what is needed to support a web browser, mouse, and sound card. The methods described make use of auditory signals which serve as corrective feedback information for users as they attempt to learn geographic data from these maps. The mental model is built by tracing paths and locating objects on the maps. We claim that the user's activity of tracing and location discovery constructs a mental model through motion of the hand - the reverse of the process by which blind users draw objects which they have never seen. Experiments evaluating these methods will be reported in a subsequent paper.

[Keywords: map exploration, blind, visually impaired, sonic feedback]

1. INTRODUCTION

There has been significant research into making computer-based graphic information available to blind users. To accomplish this the senses of hearing and touch are used. They are used in screen readers, tactile interfaces, and haptic interfaces. All of these technologies require specialized hardware and software, most of which is not free, nor is it generally available on all computers as standard equipment.

We distinguish the goals of this paper's problem from that of helping blind users navigate through everyday three-dimensional space; our problem is one of navigating through the information which represents reality, rather than reality itself.

The methods described in this paper are intended to allow exploration of the graphical data inherent in geographic information; sighted users take this graphic information for granted when presented with a map. The methods will collectively be referred to as the Geographic Sonic Explorer, or GeoSonX. The information first made accessible is characterized as paths and points. Paths are of two types: dividing or flowing. Dividing paths include exterior or interior map boundaries, and define political entities or bodies or water. Flowing paths include roads for cars or trains, and rivers. Point objects are locations such as cities, bomb locations, elevation markers, and places of interest, which become dimensionless when map scale is sufficiently large.

1.1. The Problem

An example of the problem addressed by GeoSonX is that of a blind user encountering the well-known map in Figure 1, the cholera map by Dr. John Snow depicting the 1854 London epidemic. The goal is to enable such a user to experience this map and acquire a visual sense of its information, no less than would a sighted user.

Figure 1. *Map by Dr. John Snow showing the clusters of cholera cases in the 1854 London epidemic.*

Consider next the map in Figure 2. This is a hypothetical, simplified map which shows the map elements that GeoSonX currently addresses. It contains seven paths - one boundary, three roads, two railroad tracks, and a river, and four point objects – two cities and two airports.

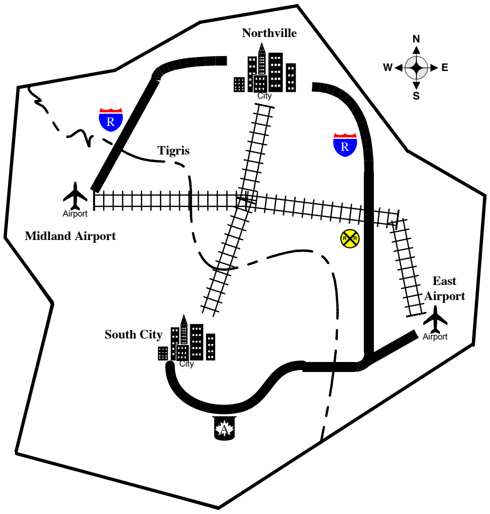

Figure 2. *A simple map containing one boundary, paths in the form of roads, railroads, and river, and four point objects in the form of cities and airports.*

1.2. Related Work

Research has been carried out in a number of fields related to ours. The paths of research include:

(1) GPS-enabled navigation devices for the blind [1][2][3][4]
(2) Geo-referenced data sonification and the attempt to make it universally accessible [5][6][7]
(3) Tactile navigation of maps, using special hardware [8][9]
(4) Sonification of graphs [10][11][12]

The work in area (1) is aimed at helping the blind navigate from place to place on the earth. It is not specifically concerned with the discovery of geographic information from representation information, such as maps. The work in area (2) is interested in geographic-referenced information, but not the graphic relationships inherent in the pictorial aspects of the map, but rather quantitative or qualitative data which is related to regions on the map. The work in field (3) is partially concerned with the geometric relationships in the data, but only as it is been made tactually discoverable. The work in area (4) is also concerned with adding sonification to visualization of graphs as an aid to comprehension, not as a means of discovering graphic relationships by blind students.

Plaisant [7] suggests that one of the limitations of the mouse is that it is an input device providing only relative positioning so absolute position on the map has to be provided by audio feedback. In this case the author was referring to voice feedback of position, rather than the types of corrective signals which GeoSonX will use.

The motivation for creating GeoSonX is to enable a blind user to experience a map in as similar a way to a sighted user experiencing the map. Since the visual experience of a map happens by letting the eyes move around the map, trace boundaries and paths, look for objects on the map, and read the text on a map, this is what GeoSonX directly attempts to bring to the blind map explorer.

2. DESCRIPTION OF DISCOVERY METHODS

This section describes the three primary ways in which GeoSonX attempts to make exploration of geographical maps accessible through sound.

First, however, we present a hypothetical description of exploration and navigation in real geography to provide a context for and conceptual path to these methods. Consider a blind person who moves to Jerusalem and needs to walk from Herod's Gate through the Old City to Jaffa Gate every day. She attempts to stay in the middle of the path as someone has defined it. She beings walking on the path. As she walks she begins to veer to the right; immediately, she hears a sound which tells her to change direction slightly to the left. When she is near the middle of the path she hears a pleasant quiet sound letting her know that she is walking in the right place. She completes her path successfully. She repeats it several times, needing sonic correction feedback less and less. She eventually feels that she knows the path. The path is somehow represented in her brain; she can describe its twists and turns, although not necessarily accurate to within even a centimeter. This is the general idea behind GeoSonX, although traversal and discovery will be on a much smaller scale, and rather than movement of feet, the user's hand moves her mouse.

2.1. Discovering Paths to build visual mental models

Figure 3 is a map composed of a single square path. The GeoSonX path discovery method aids the user in tracing the path with the mouse. Assume that the mouse is near the southwest corner and the user starts to move the mouse east.

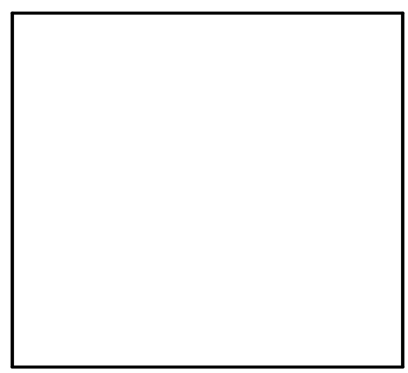

Figure 3. *A simple outline map*.

Suppose the user begins to deviate from the boundary path. How can GeoSonX bring the user back to the path? Figure 4 shows the solution. If the user deviates with a positive angle, a positive corrective sound is played. If the user deviates with a negative angle, a negative corrective sound is played. In either case, the user knows the direction in which to move the mouse to get back to the path. The corrective signal is played until the mouse is brought back to within **t** of the path, **t** representing a tolerance. Tracing a path repeatedly may result in a user learning the path. If the path has been learned to within **t** of the original object, we defined the path to be known to within **t**. The person using GeoSonX can modify the value of **t**. As the value of **t** approaches 0, the object is said to be known perfectly in the sense of its reproduction or recognition. Figure 4 shows the map of Figure 3 with a region of size **t** on either side. Note that for many purposes, knowing a map boundary to within some non-zero tolerance may be as useful as knowing it perfectly.

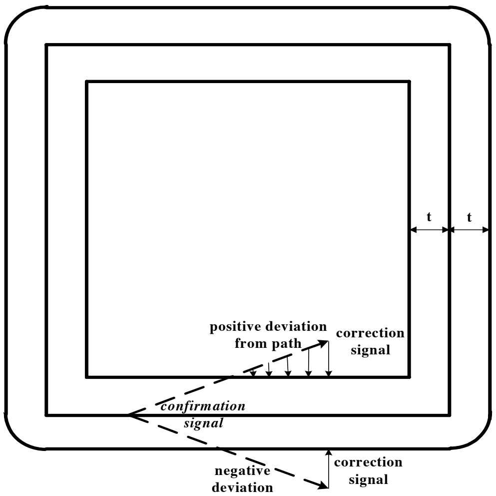

Figure 4. The Figure 3 map showing regions of tolerance **t** on either side of the original path.

2.2. Discovering objects on the map.

How does GeoSonX help the user discover objects on a map?

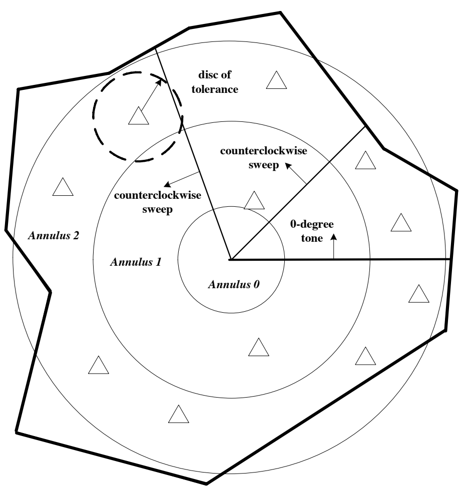

Figure 5. *A sonar-like sweep discovers objects. The disc of tolerance covers the next object to be discovered.*

Consider Figure 5. It is a map containing point objects, signified by triangles. The points could be the pumps and cases of cholera of Fig. 1, or the airports of Fig. 2. GeoSonX discovers these objects, and reports their existence via sonification. It creates a ray, which may be centered on the map, and which sweeps counterclockwise. As the ray enters a circular area centered on each new object the user hears a signal of discovery. The user may change the radius of the tolerance disc to find objects more precisely. If the user is overwhelmed by the number of objects discovered, s/he may divide the plane into a set of concentric annuli, also of adjustable width. The center of the ray of object discovery may also be moved.

This leaves another problem: once an object is discovered how does the user determine its location? The next section discusses a solution.

2.3. Discovering locations of individual objects.

GeoSonX has used auditory signals to indicate a success condition, and either of two opposite conditions requiring correction. This is the basis for path exploration. The same general approach may be used for object location. An object to be located is considered situated in the center of a disc of radius **t**. The mouse is considered to be at the center of cross-hairs. Location is done in two steps; first, longitude is found; then, latitude is found. If the projection of the disc onto the dimension being determined includes the mouse, the success signal is heard. Otherwise, either of two correction signals is heard, alerting the user to move the mouse closer to the object, north/south for latitude detection and east/west for longitude. Figure 6 illustrates object location.

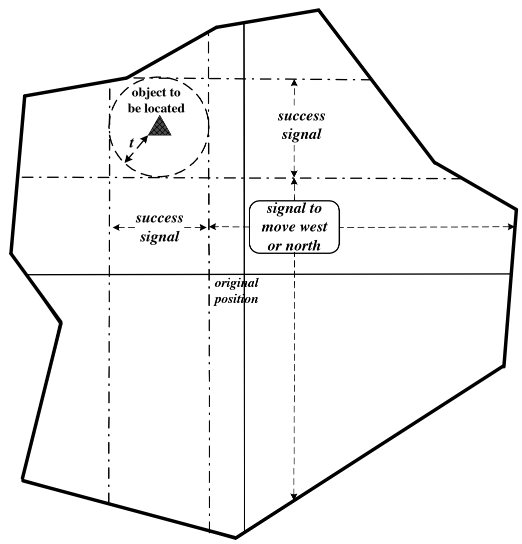

Figure 6. *Using north/south or east/west signal plus success signal to locate object*

3. COGNITIVE JUSTIFICATION

What is the cognitive process by which GeoSonX will be able to achieve any degree of success? One of the results of using GeoSonX is a mental model of the graphic elements of a map. No one knows what such a mental model looks like, or how it is realized in the brain. However, it is a working assumption of cognitive science that such mental models do exist. The question for GeoSonX is, can a mental model of a map be created using its methods of map exploration and discovery?

The simple steps by which a map visualization is created is an iterative process, facilitated by repetition and feedback. It begins when the user moves the mouse to explore a path. Either of two events occurs: the user moves the mouse along the path, to within the acceptable tolerance, or moves out of the acceptable region. Both of these actions cause confirmatory signals, either success or correction. If the user chooses to correct the path s/he is able to trace part of the path successfully. The action of moving the mouse along the path begins to build a visual representation of the path. Experimentation will be needed to quantify the degree to which repetition of the path reinforces successful performance of path reproduction. Experimentation is also necessary to find out how small a tolerance can be achieved for path and object discovery.

Research has been done with blind subjects who have demonstrated the ability to create drawings of realistic objects, including the use of perspective [13]. Several lines of research have studied blind artists [17][18] to understand how they 'visualize' reality before drawing it. This work has made use of drawing tools for the blind, which are primarily tactile in design, although [17] has described the addition of sonification to the forms of feedback for the blind artist.

From the perspective of GeoSonX the notion of defining the learning of a map will be replaced with quantifying the performance of recall and recognition. The details of this activity are left to a follow-up paper.

We believe the introduction of the notion of exploration of inherently graphical entities, such as maps, within a level of tolerance, will aid the blind user in experiencing maps. Christian [19] has pointed out that certain types of motor-control problems are difficult even for sighted users. These include straight line drawing with a mouse. Removing the restriction of perfect performance or discovery should overcome this problem.

4. TECHNICAL ISSUES

Many details remain to be defined for a specific implementation of GeoSonX. GeoSonX requires data, software, and hardware. We describe some alternate approaches below.

4.1. Sonification signals

Experimentation will be necessary before we know which sounds are most effective for the success and corrective signals. Trials with blind users, as well as with visually impaired users, will be necessary to determine if these two populations have different characteristics with regard to types of sonification, including, but not limited to, volume, pitch, timbre, and melody.

4.2. Coding of Geographic Information

An assumption underlying the working of GeoSonX is the existence of geographically encoded information which GeoSonX will interpret to define paths and points. The most obvious choice is the standard OpenGIS, from the Open Geospatial Consortium [21]. Its mandate is to "geo-enable" the web. At this point it is not explicitly concerned with access by blind users.

Another XML-based method of encoding geographic information has been suggested; namely, SVG (Scalable Vector Graphics) [7][22]. While an obvious choice for graphics, SVG is not specific to geographic information and would need to be extended to be useful for GeoSonX.

4.3. Implementation and Delivery of GeoSonX

The delivery mechanism of GeoSonX has not been discussed. It is possible to build GeoSonX as a standalone application using a variety of technologies. However, to be easily available on the web, some of the choices include Java-based applets, AJAX, Adobe Flash, Macromedia, and browser plug-ins.

5. EXTENSION TO OTHER DOMANS

Although GeoSonX remains to be implemented and extensively tested, it is still possible to identify additional applications of the method.

5.1. Education

The activity of discovering the visual characteristics of paths should be applicable to the teaching and learning of elementary geometry, and to coordinate geometry and the two-dimensional graphing of functions. In addition, those subject areas which use maps, such as history and geography could see a benefit to blind students who would otherwise need special equipment for exploring maps.

5.2. Science

Besides geographic information maps, there are other types of maps which may be experienced by blind users. These include weather maps and contour maps.

In the field of astronomy, the ability for a blind user to discover point objects and their locations may help them to learn astronomical constellations.

In the fields of physics and mathematics, sufficiently advanced students may be able to explore vector fields and the graphical solutions to differential equations.

6. ADDITIONAL WORK

The present proposal for GeoSonX raises a number of additional questions. These will be pursued after the efficacy of GeoSonX has been investigated. Some of the questions are:

How will GeoSonX work with input devices other than the standard computer mouse? Will it work better with pen-based tablet computers? What about finger input for large-scale discovery of map layout, since GeoSonX incorporates the notion of tolerance?

If GeoSonX proves attractive to the community of blind online users, will it be possible to provide GeoSonX and the appropriately encoded geographic data on the most popular web sites which include geographic maps? Or, should GeoSonX be delivered as a plug-in for each browser?

What is the capacity of a blind user in learning a map? How many map objects, path and point, can a user remember before forgetting some?

GeoSonX as described here is limited. It must be extended to include recognition of the end of path when exploring and signaling of the return to starting place. It is also necessary to recognize other paths crossing the path being followed, as well as different types of path intersections, making it possible to follow a different path and returning to the prior path. It is also necessary to extend GeoSonX to recognize paths of non-zero width, such as those shown in Fig 1, the cholera map.

Inherent in each map explored is the scale of the map. How does a user make the transition from 'point' objects to objects of non-zero area as the scale of the map decreases?

How can GeoSonX deal with map features which are neither paths nor point objects, object such as topography or other more amorphous features?

GeoSonX needs to define its method of providing non-graphic information, such as names, longitude, latitude, geographic-referenced data, etc. Finding an object and then identifying it is required. The converse is also required; namely, finding a name of a path or point, and then finding it on the map.

7. CONCLUSIONS

We hypothesize that GeoSonX will make online maps accessible to blind users so that they can understand the graphic relationships on the maps, not just the textual data. Further, we expect that if GeoSonX achieves this goal, it will also prove useful in other domains.

8. REFERENCES

[1] Kay, L. A Sonar Aid to Enhance Spatial Perception of the Blind: Engineering Design and Evaluation. in Radio and Electronic Engineer. 1974.

[2] Borenstein, J. and I. Ulrich. The GuideCane - A Computerized Travel Aid for the Active Guidance of Blind Pedestrians. in Proceedings of the IEEE International Conference on Robotics and Automation. 1997.

[3] Ross, D.A. and B.B. Blasch. Wearable Interfaces for Orientation and Wayfinding. in The Fourth International ACM Conference on Assistive Technologies. 2000.

[4] Helal, A., S. Moore, and B. Ramachandran. Drishti: An Integrated Navigation System for Visually Impaired and Disabled. in Proceedings of the 5th International Symposium on Wearable Computers. 2001.

[5] H. Zhao et al., "Sonification of Geo-Referenced Data for Auditory Information Seeking: Design Principle and Pilot Study," in *Proc. Int'l Conf. Auditory Display*, Int'l Community for Auditory Display, 2004

[6] H. Zhao, C. Plaisant, and B. Shneiderman, "I Hear the Pattern - Interactive Sonification of Geographical Data Patterns," *ACM SIGCHI Extended Abstracts*, ACM Press, 2005

[7] C. Plaisant, "Information Visualization and the Challenge of Universal Access," *Exploring Geovisualization*, in J. Dykes, A. MacEachren, and M.-J. Kraak, eds., Elsevier, 2005.

[8] Jacobson, R.D., "Navigating maps with little or no sight: An audio-tactile approach," Proceedings of the Workshop on Content Visualization and Intermedia Representations (CVIR), 1998.

[9] P. Parente, G. Bishop, "BATS: the blind audio tactile mapping system" in *Proc. ACM Southeast Regional Conf.* 2003.

[10] T.L. Bonebright et al., "Testing the Effectiveness of Sonified Graphs for Education: A Programmatic Research Project," in *Proc. Int'l Conf. Auditory Display*, Helsinki Univ. of Technology, 2001, pp. 62-66.

[11] L. Brown and S.A. Brewster, "Drawing by Ear: Interpreting Sonified Line Graphs," in *Proc. Int'l Conf. Auditory Display*, Boston Univ., 2003, pp. 152-156.

[12] J. Flowers, D. Buhman, K. Turnage, "Cross-Modal Equivalence of Visual and Auditory Scatterplots for Exploring Bivariate Data Samples," in *Human Factors*, vol. 39, no. 3, 1997, pp. 341-351.

[13] J. Kennedy, I. Juricevic, I. "Haptics and projection: Drawings by Tracy, a blind adult" in *Perception*, 2003, 32, 1059-1071

[14] L. Boelke and P. Gorny, "Auditory Direct Manipulation in Acoustical Objects by Blind Computer Users," in International Conference on Auditory Display (ICAD), Santa Fe, USA, November 1994.

[15] P. Gorny: Typographic semantics of web pages accesible for visually impaired users – Mapping layout and interaction objects to an auditory interaction space –, Proc. of ICCHP 2000, pp.251–257, 2000.

[16] B. Richardson, "Touching a Virtual World: What can it teach us?", in *CAL-laborate* Volume 4 June 2000, http://science.uniserve.edu.au/pubs/callab/vol4/

[17] H. Kamel , J Landay, "A study of blind drawing practice: creating graphical information without the visual channel", in *Proceedings of the fourth international ACM conference on Assistive technologies*, p.34-41, November 13-15, 2000, Arlington, Virginia, United States

[18] H. Kamel , J. Landay, "Sketching images eyes-free: a grid-based dynamic drawing tool for the blind", in *Proceedings of the fifth international ACM conference on Assistive technologies*, July 08-10, 2002, Edinburgh, Scotland

[19] K. Christian, "Design of Haptic Tactile interfaces for blind users.", 2000, http://www.otal.umd.edu/ UUGuide/kevin/

[20] S. Mereu, R.Kazman, "Audio Enhanced 3D Interfaces for Visually Impaired Users", in *Proc. Int'l Conf. Auditory Display*, Int'l Community for Auditory Display, 6-9 July, 2003. Boston, MA

[21] http://www.opengeospatial.org/standards

[22] http://www.w3.org/Graphics/SVG/